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## Stellar Fossils: Globular clusters as probes of the galaxy

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*Utah State University*

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# **STELLAR FOSSILS: GLOBULAR CLUSTERS AS PROBES OF THE GALAXY**

**Shane L. Larson  
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**Astronomical League Convention — ALCON  
Bryce Canyon National Park  
1 July 2011**



# Storyline

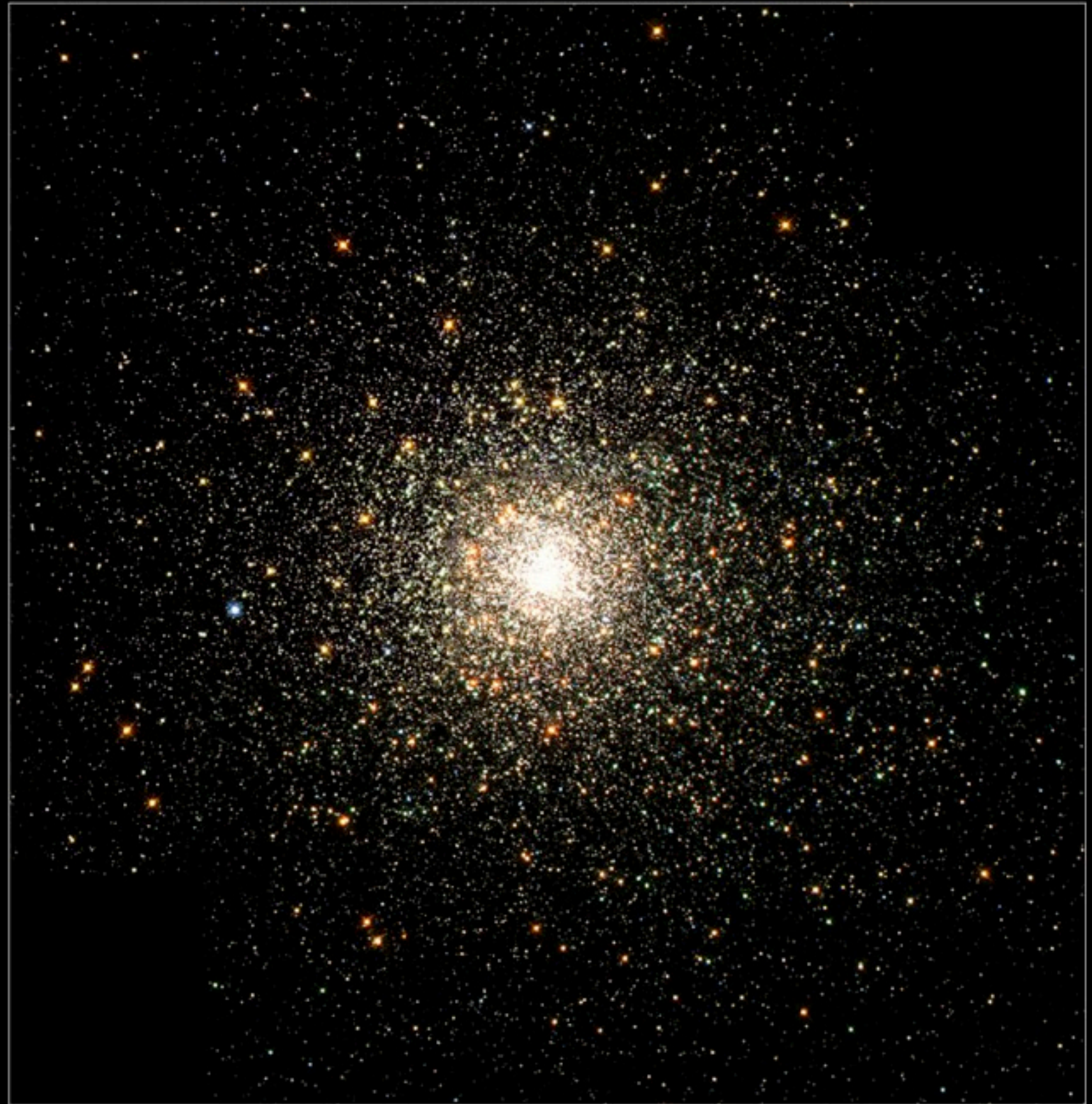
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- Some history
- Some science (about age)
- Globs to observe!

***There is far more  
than we can talk  
about in one talk!***

***Please ask questions!***

Globular Cluster NGC 6093



**M80 (NGC 6093)  
(Scorpius)**

Hubble  
Heritage

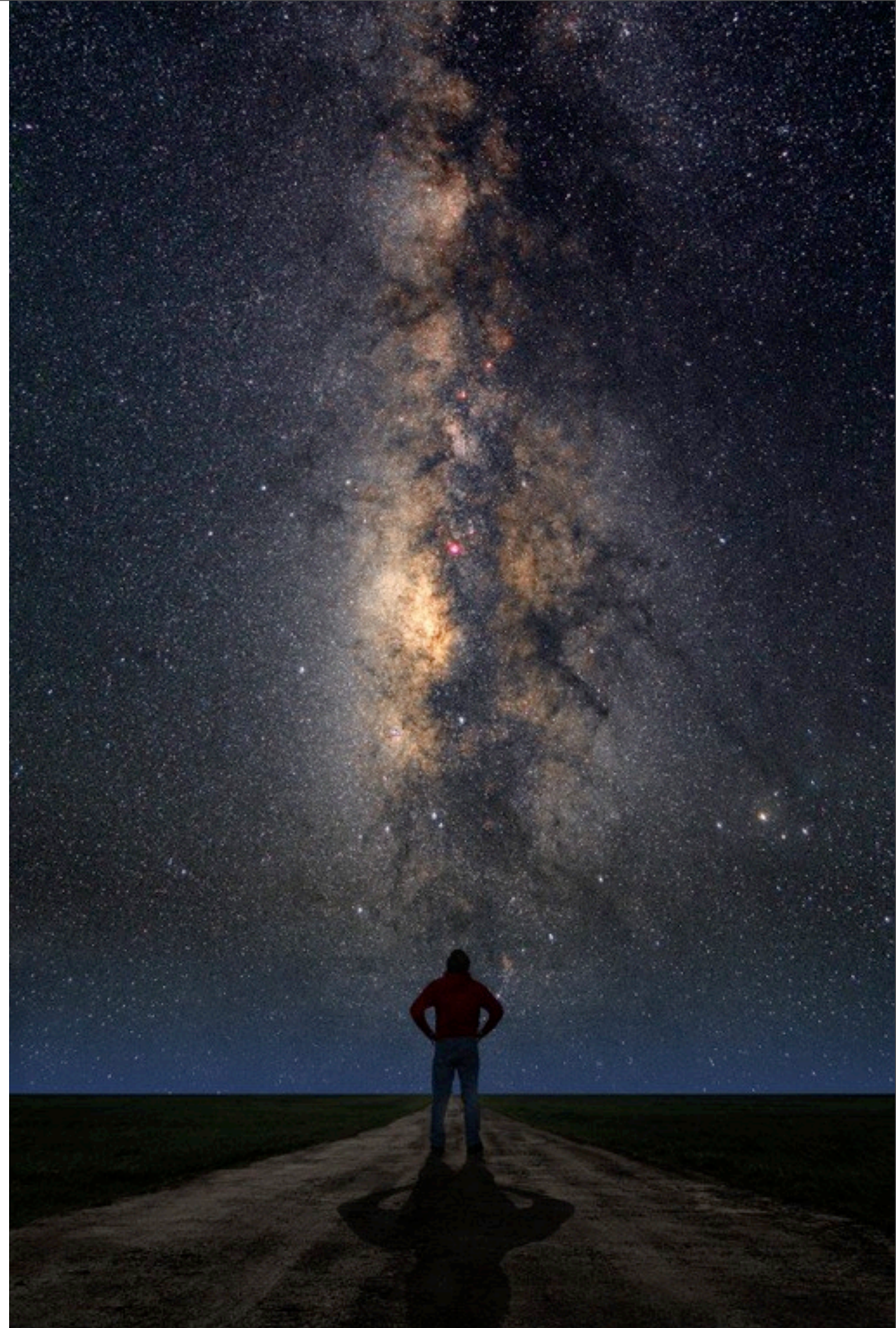


# *Galactic skies...*

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- At night **the Milky Way** stretches overhead, a vast backbone supporting the sky (especially at Bryce!)
- The cloudy nature of its appearance was not well understood until the invention of the telescope
- Embedded in the night sky are innumerable dark lanes and brighter areas that we identify as **deep sky objects**

***Smudges***

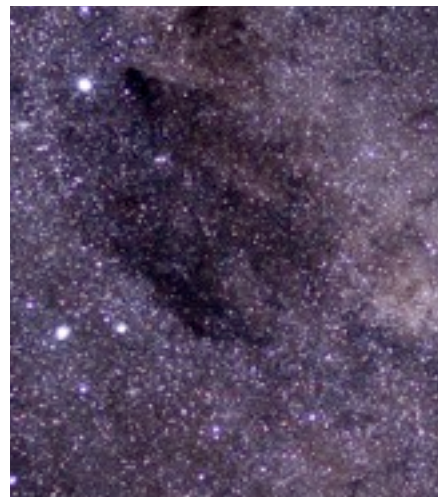
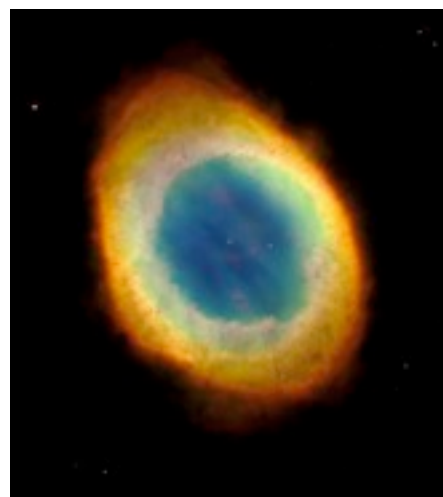
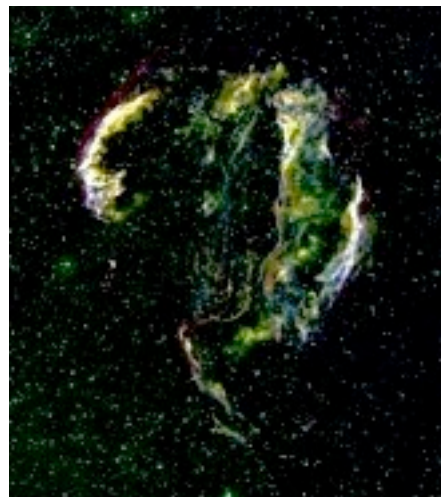
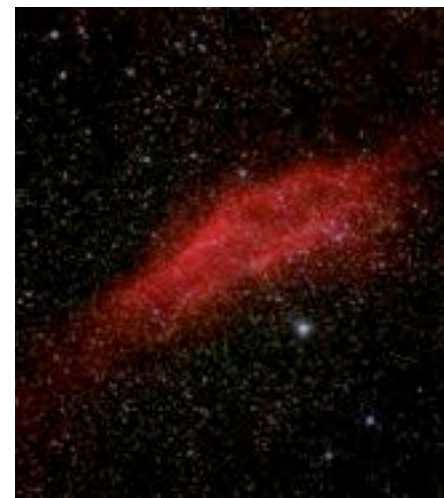




# *The Deep Galaxy*

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- Telescopes revealed the composition of the galaxy: all the beauty and wonder of the Deep Sky
- Many fuzzy blobs are visible to the naked eye. Most look like fuzzy blobs through the scope, but many do not
- Galaxies, nebulae, **star clusters**



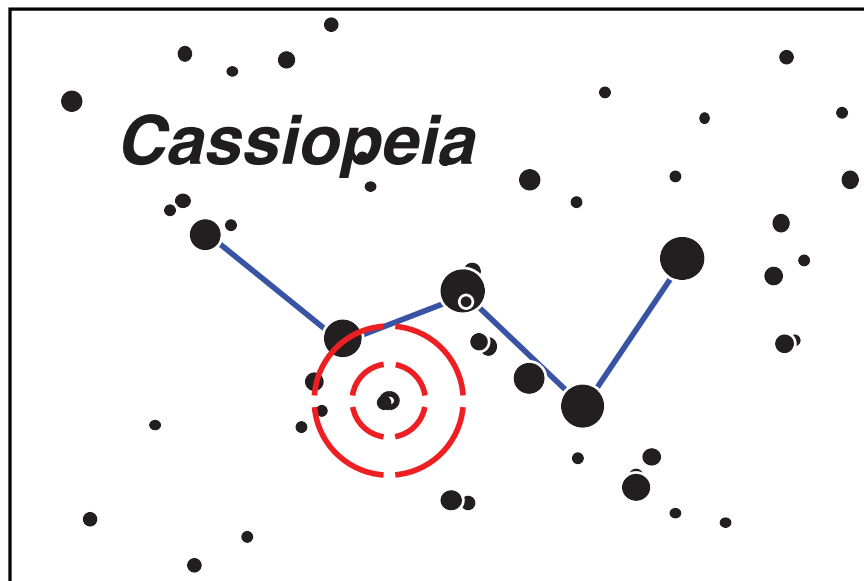


# Star Clusters

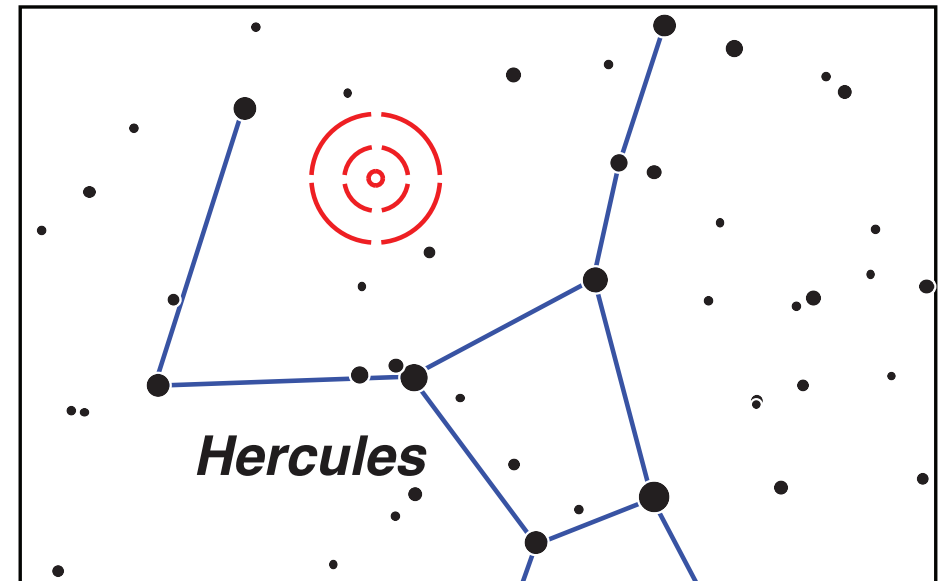
**ET Cluster (NGC 457)**



**M92**



**OIY**





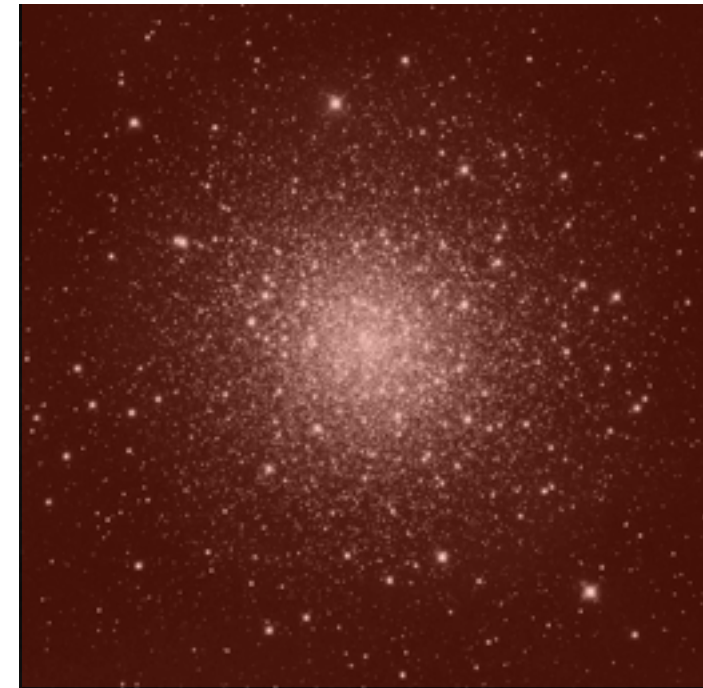
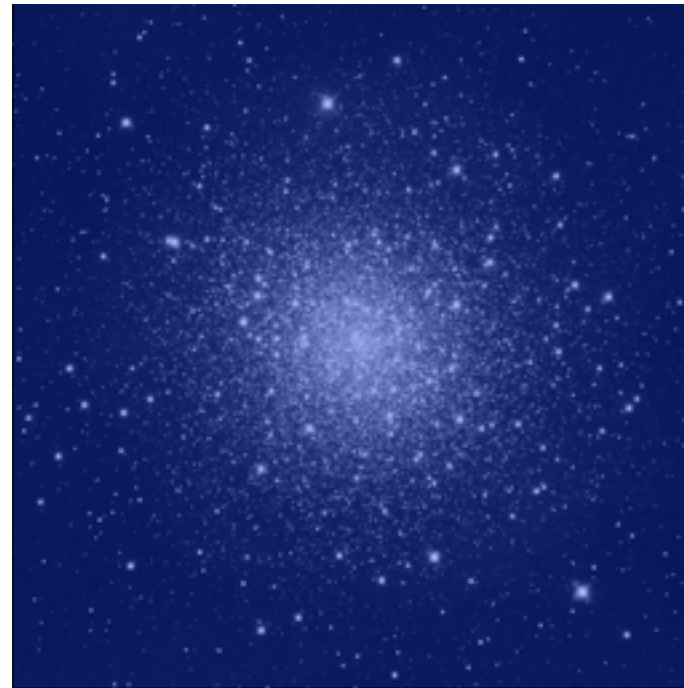
# Star Clusters



- Star clusters come in two basic types which we can (more or less) identify visually
- **Open Clusters:** ~hundreds of stars, typically bluer in color
- **Globular Clusters:** hundreds of thousands of stars, typically redder in color
- As it turns out, the astrophysical story distinguishes these two cluster types and defines their appearances



# Measure the color yourself...



- You should do this with standard filters (UBVRI, ugriz), but any filters will work (as long as you are consistent in what you do, and keep good notes!)
- Image the cluster through one filter (**bluer end of spectrum**); measure the brightness ***F1***
- Image the cluster through a second filter (**redder end of spectrum**); measure the brightness ***F2***
- The color is the difference in these two brightnesses:  **$COLOR = F1 - F2$** 
  - A large number means bluer color, a smaller/negative number means redder
  - When astronomers talk about “***B–V colors***” this is all we are doing



# The “Discovery” of the Globular Clusters



- At first, we didn't know they were star clusters! Early telescopes were not so great...
- The first glob discovered was M22 by Johann Abraham Ihle, who was observing Saturn in 1665 and noted a “**composite nebula between the head and the bow of the archer onto which a great number of faint stars was projected**”
- Messier was the first to resolve individual stars in M4 in 1764!



# *Shapley 1918: Where are the globulars?*

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**Harlow Shapley**

42

PUBLICATIONS OF THE

## GLOBULAR CLUSTERS AND THE STRUCTURE OF THE GALACTIC SYSTEM

BY HARLOW SHAPLEY

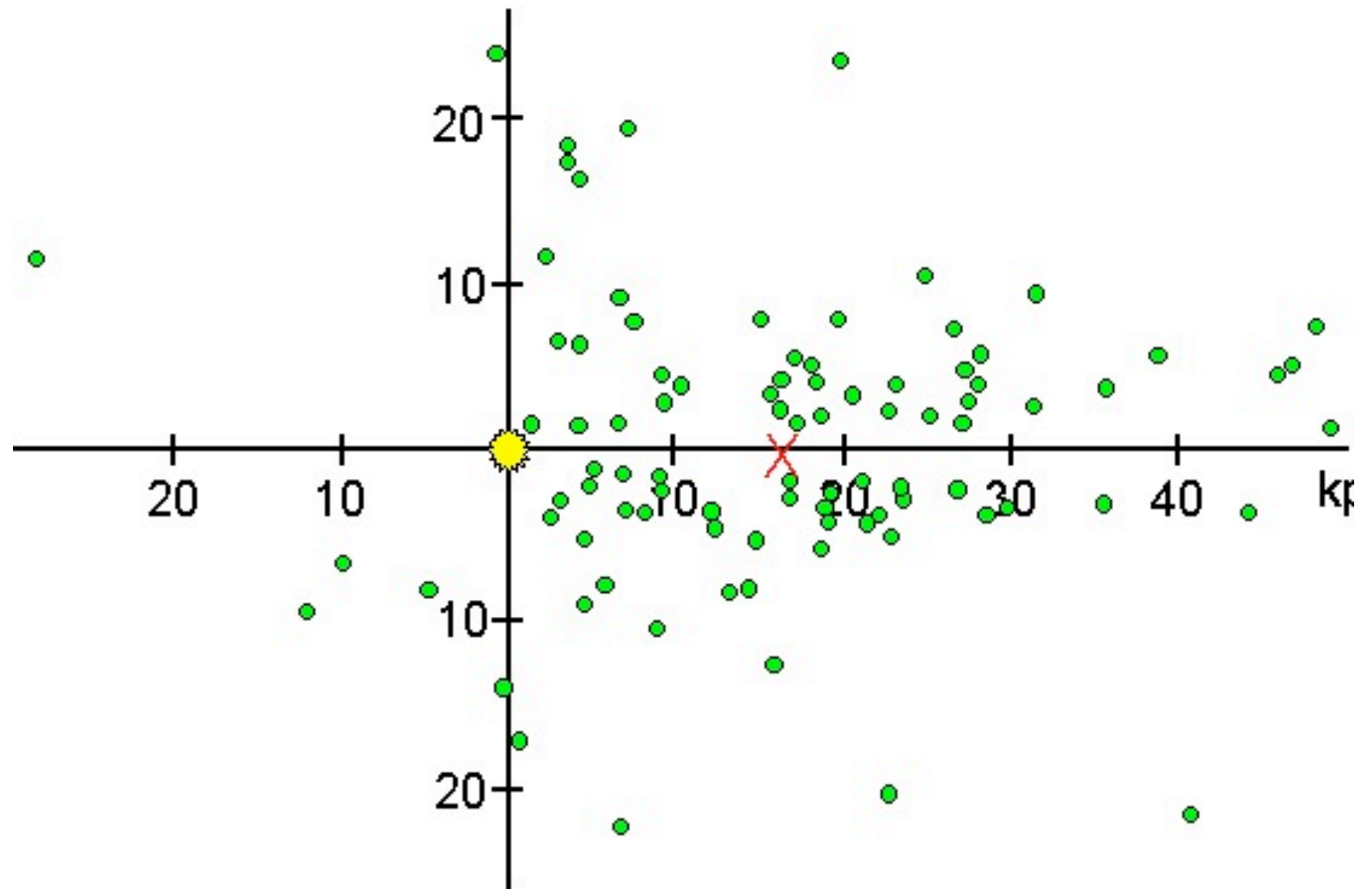
The continuation of my work on clusters has yielded information that seems to have some significance in the problem of the extent and arrangement of the general sidereal system. During the past two years the magnitudes of several thousand stars in thirty globular clusters have been measured, some rather extensive studies of variable stars and open clusters have been carried out, and methods have been investigated for the determination of the distances of clusters and variables. The results are discussed at length in several contributions from the Mount Wilson Solar Observatory, which are now in process of publication and will appear within a few months. Meanwhile the more striking features may be briefly outlined, omitting, as is necessary for an article of this kind, the computations and numerical tables. In fact, the present announcement can be little more than a summary of methods, observations, and conclusions, and indulgence must be asked for presenting these results in advance of the observational material upon which they are based. The accompanying diagrams, however, may partially serve in the place of tabular data.



# Shapley 1918: Where are the globulars?

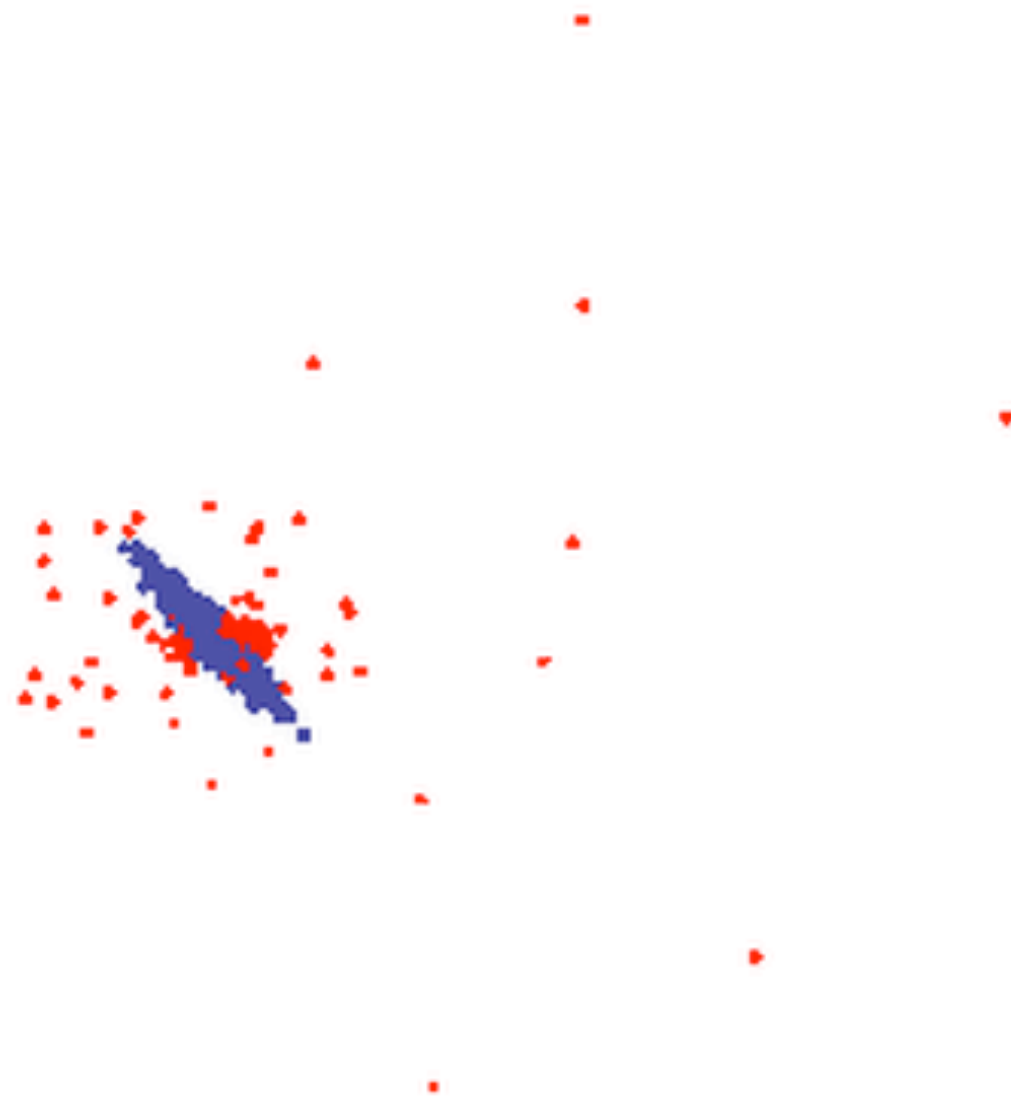


**Harlow Shapley**



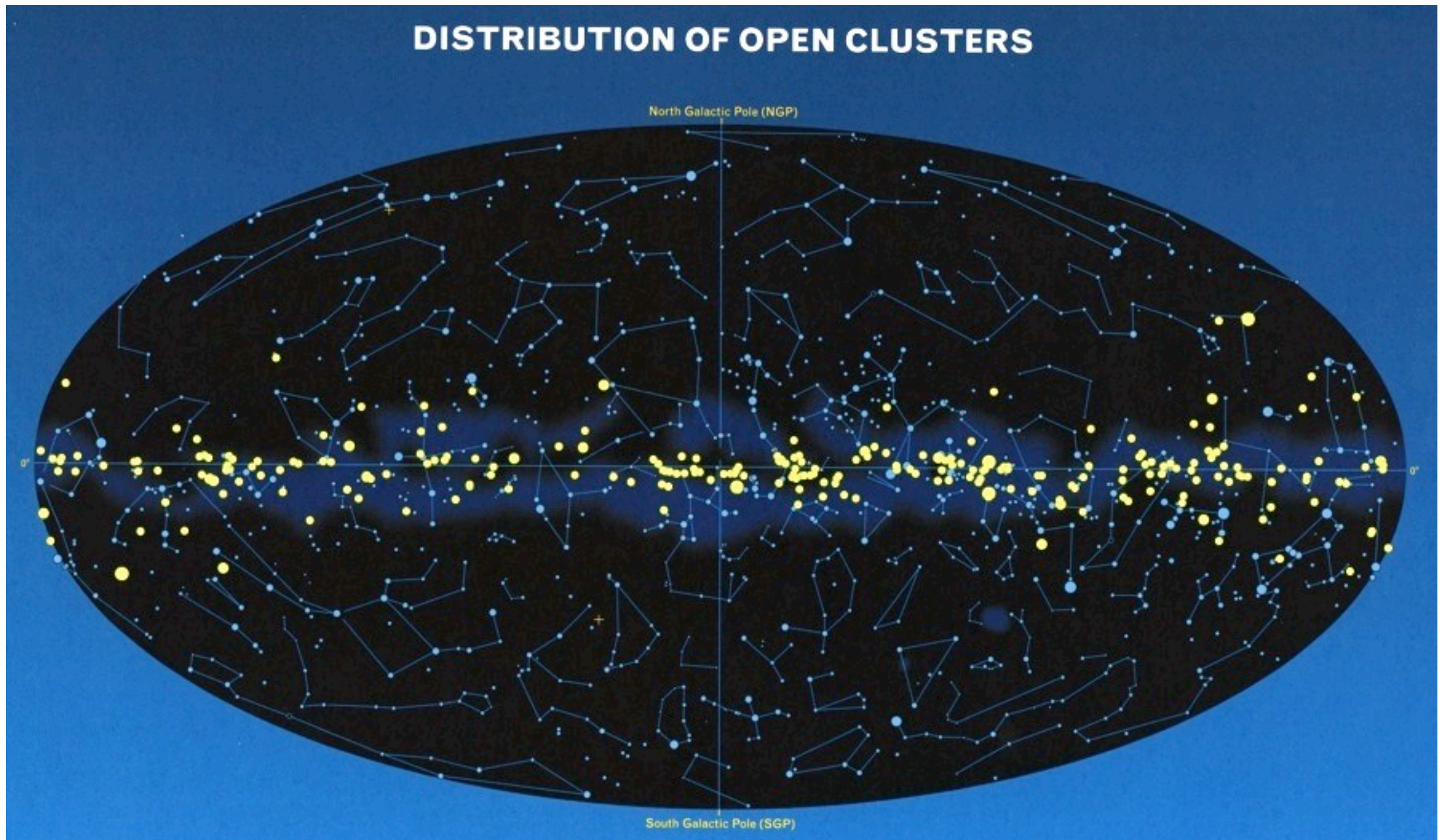
- Harlow Shapley was the first person to map out the location of the globular clusters, and he made a startling discovery — **they are centered away from Earth!**
- He reasonably assumed they were centered on the Milky Way, and made the **first estimate of the distance to the galactic center**







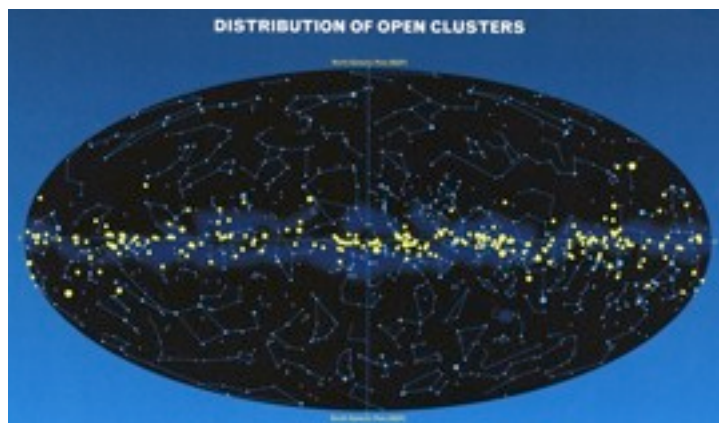
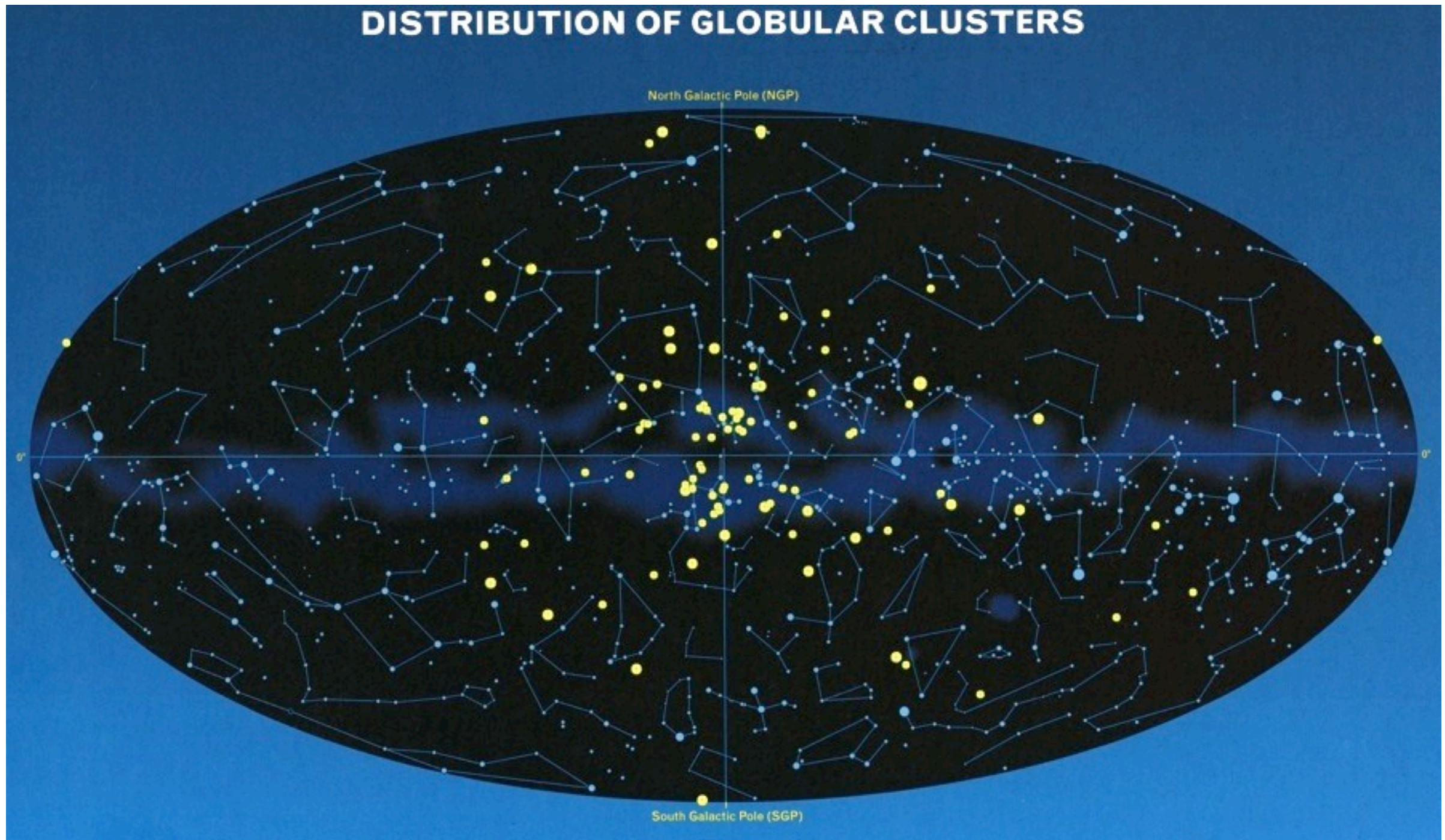
# Where are the clusters?



- If you compare the distribution of globular clusters to open clusters, you notice a distinct difference
- Open clusters are **concentrated on the disk**, whereas globular clusters are **distributed through the halo**.



# Where are the clusters?

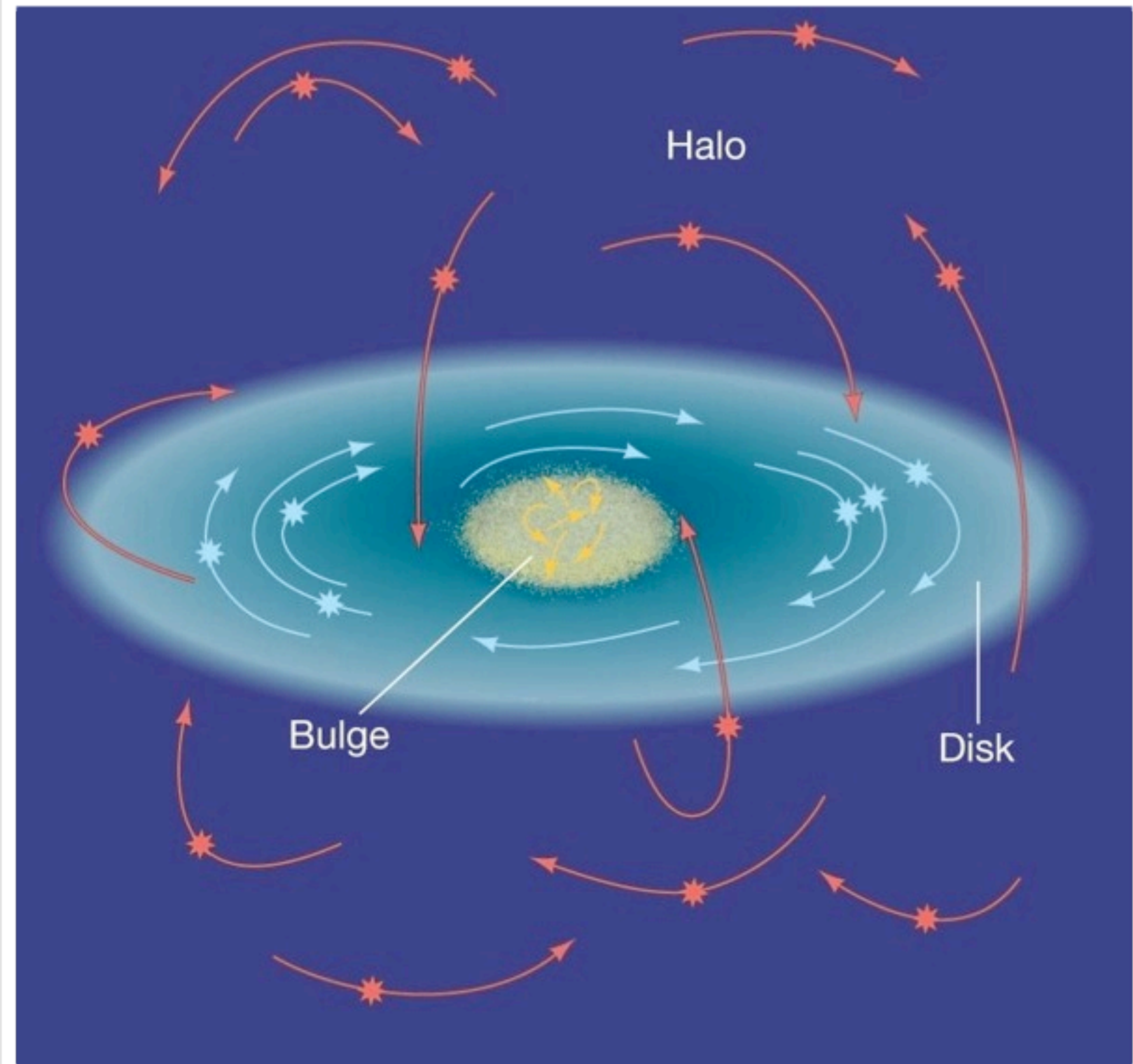


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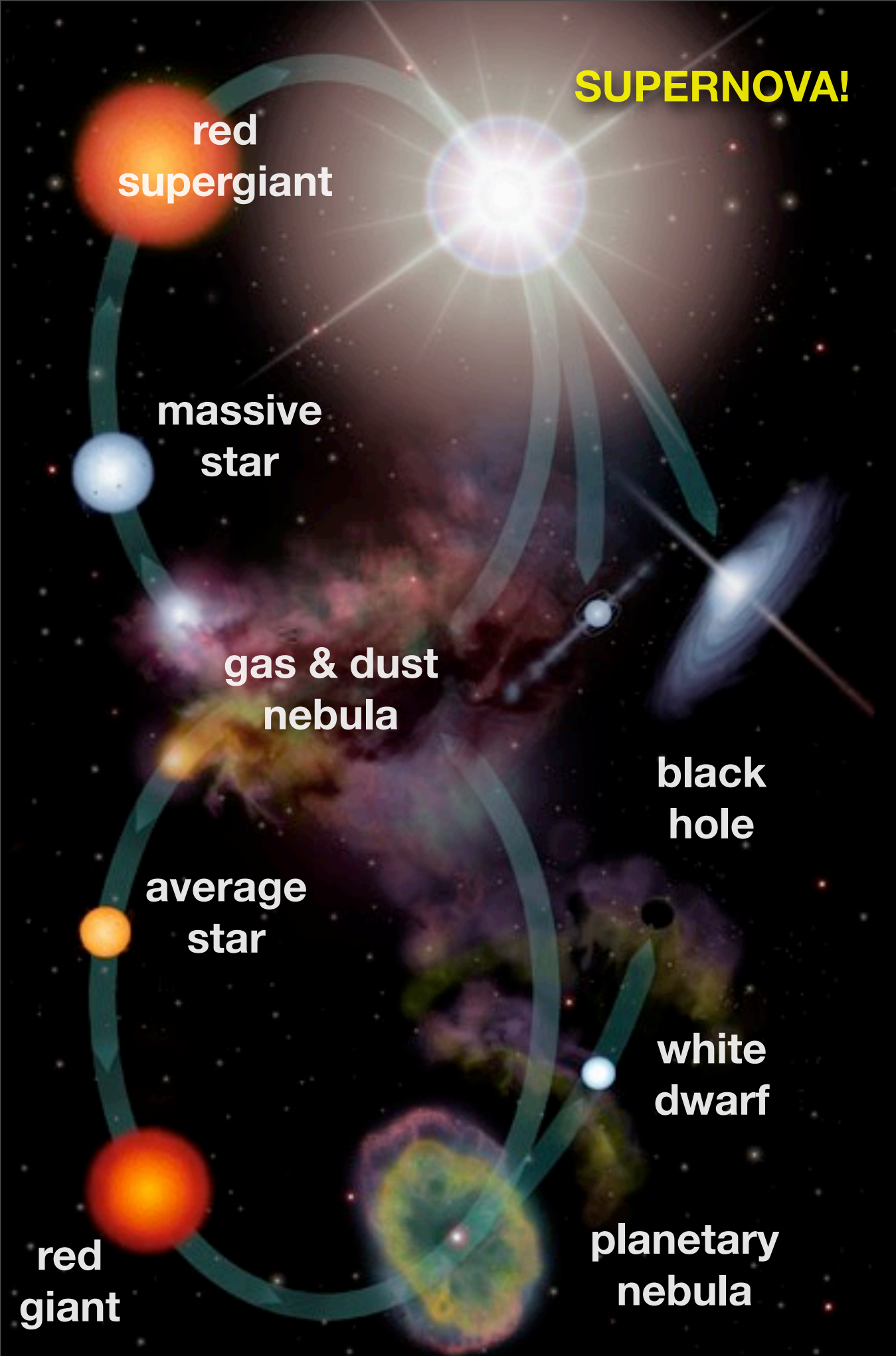


# Some Basic Facts

- There are approximately 150 globular clusters in the Milky Way (maybe ~50 to be discovered in the Zone of Avoidance)
- They are bound to the Milky Way, orbiting the galaxy just as individual stars like the Sun do
- The globular clusters are **old**, home to the oldest known stars in the Galaxy
- How do we know that?
  - Metallicity
  - HR Diagrams







## *Metallicity*

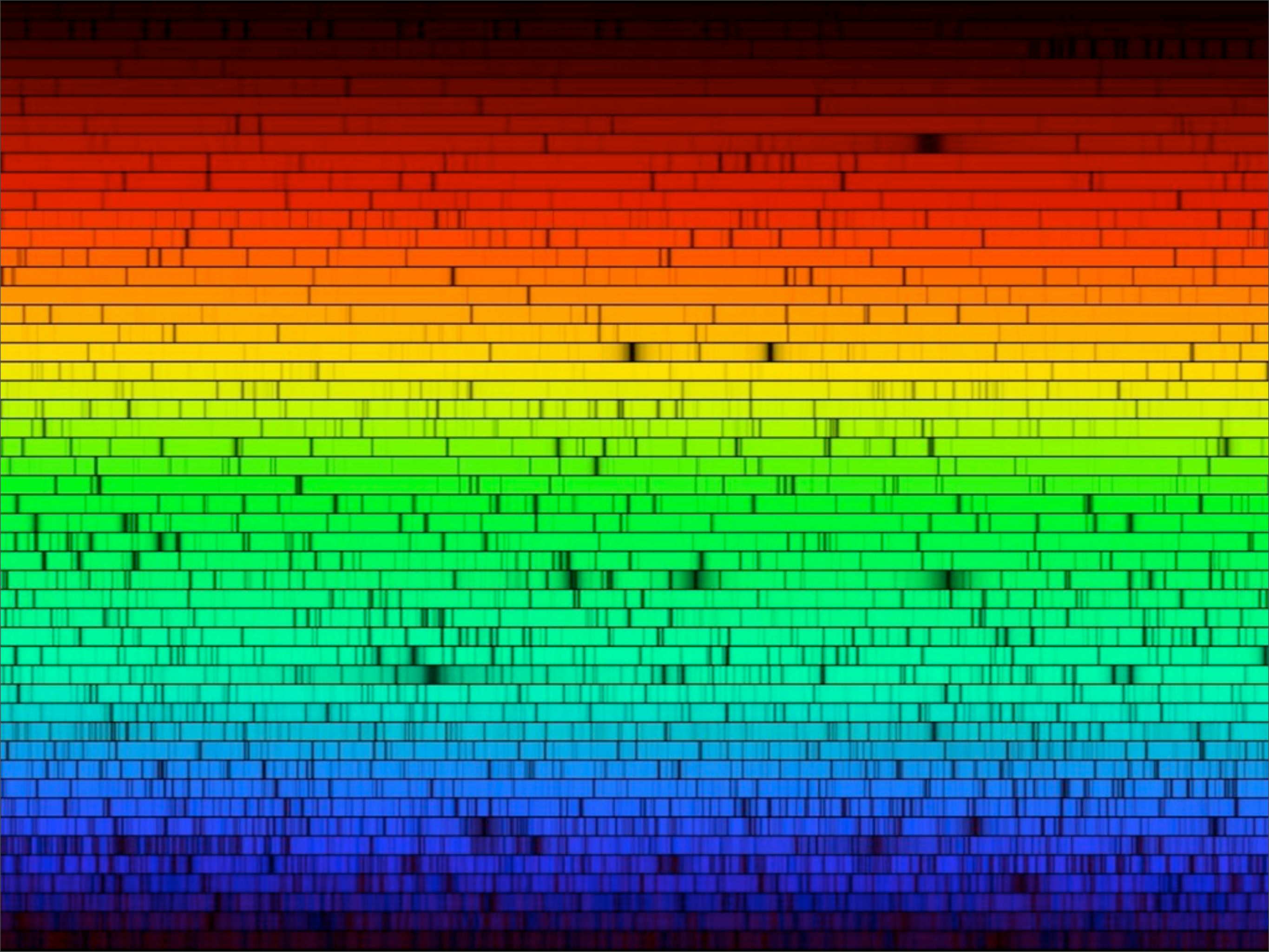
- Stars are like people: they are born, they live, and they perish.
- In the beginning, there was hydrogen.
- Stars turn hydrogen into other stuff — the 92 naturally occurring elements on the periodic table.
- For astronomers, “***if you aren’t hydrogen, then you’re a metal***”
- Metallicity is the ratio of metals to hydrogen



# Stellar Populations

- **Population I:** Metal rich stars (like the Sun); these are the youngest stars in the Cosmos
- **Population II:** Metal poor stars; these are older stars, and created most of the metals that are in the younger generation (they are Pop I parents)
- **Population III:** The oldest stars, consisting of virtually nothing except hydrogen. No known Population III star has been detected yet.
- In globs, most of the stars are Population II (metal poor)







# The HR Diagram

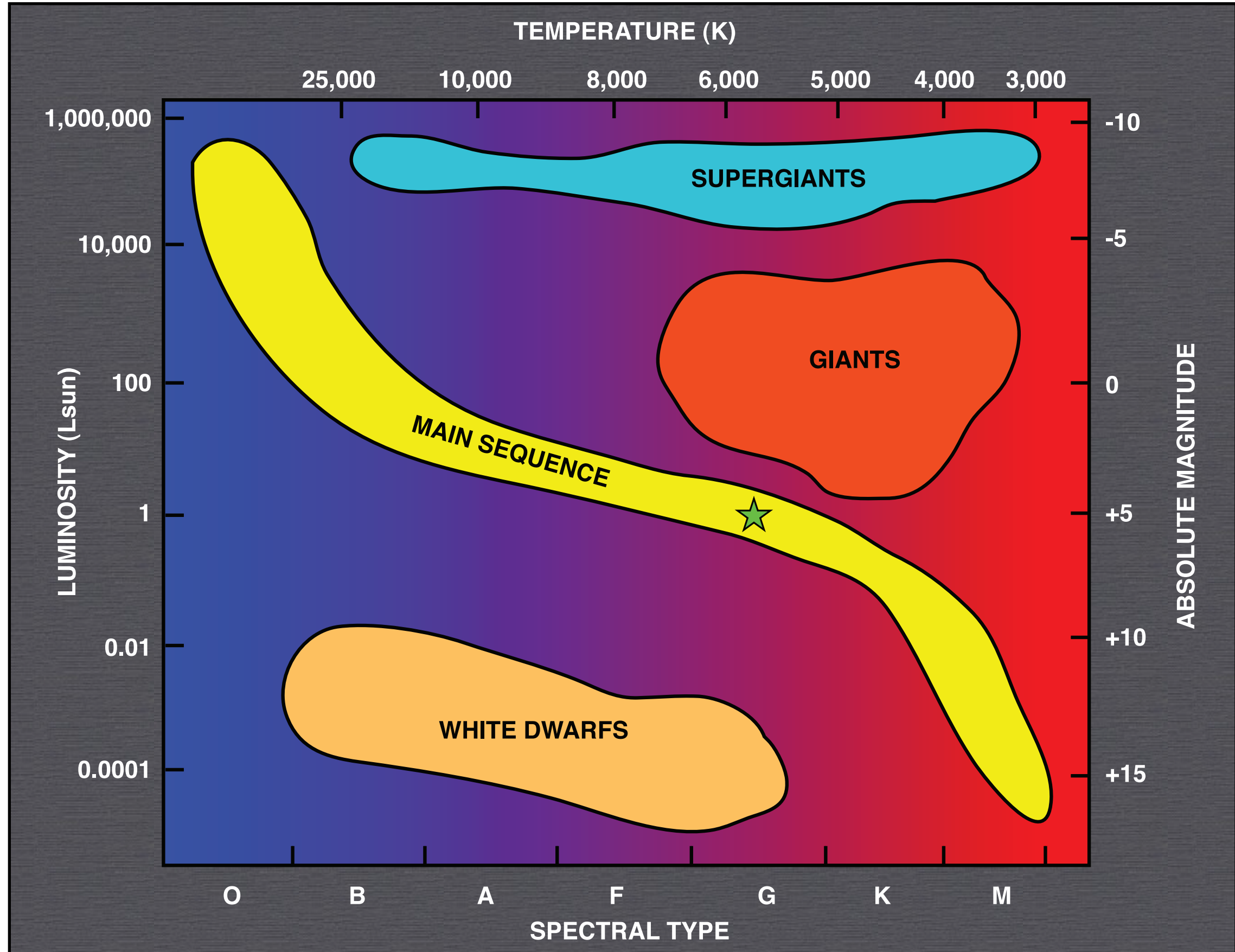
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- In ~1910, Henry Norris Russell and Ejnar Hertzsprung independently discovered one of the most important tools known to astronomers
- They were looking for **dependencies between stellar properties** (mass, size, brightness, temperature, color, ...)

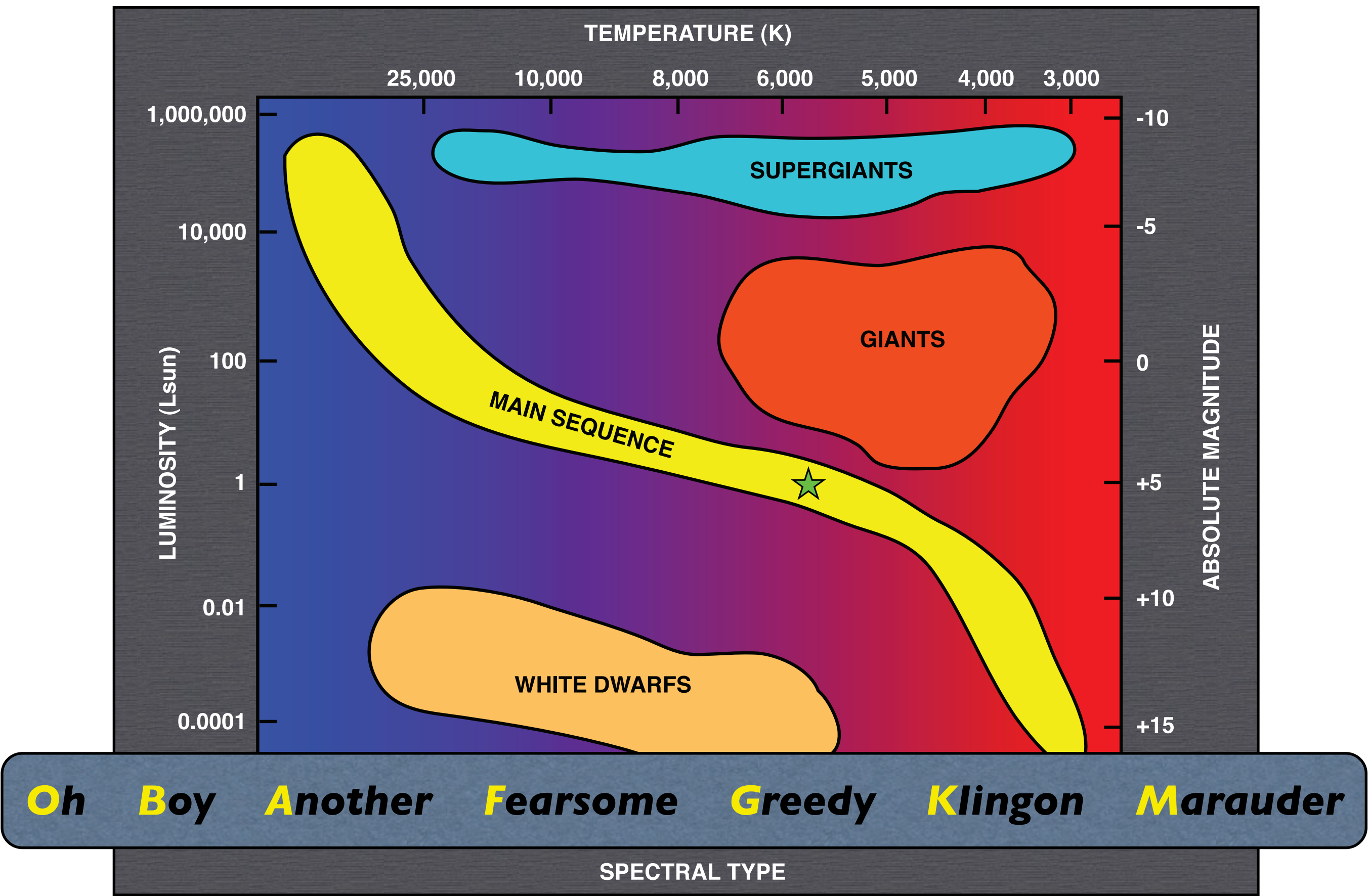


# Stars on the HR Diagram



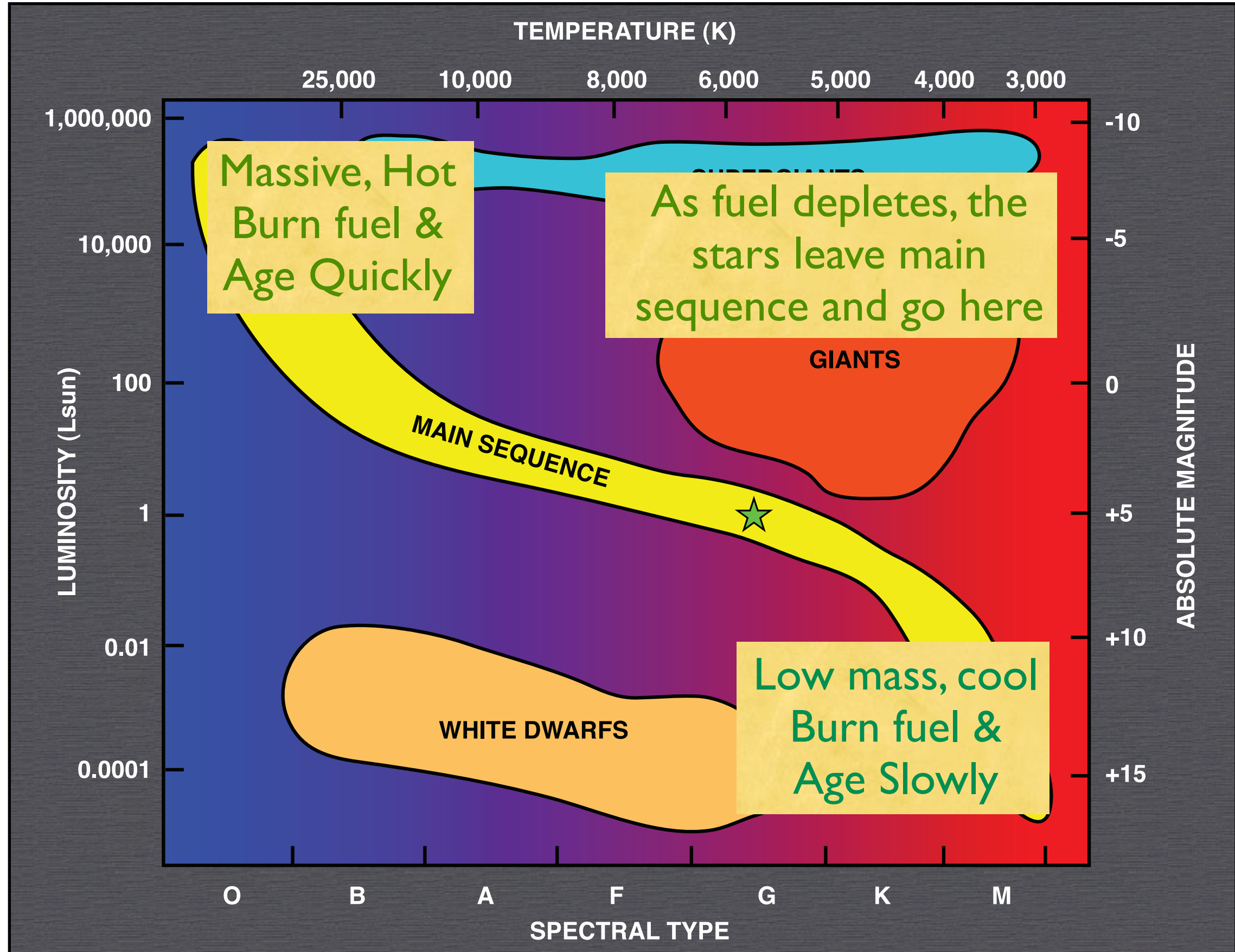


# Stars on the HR Diagram





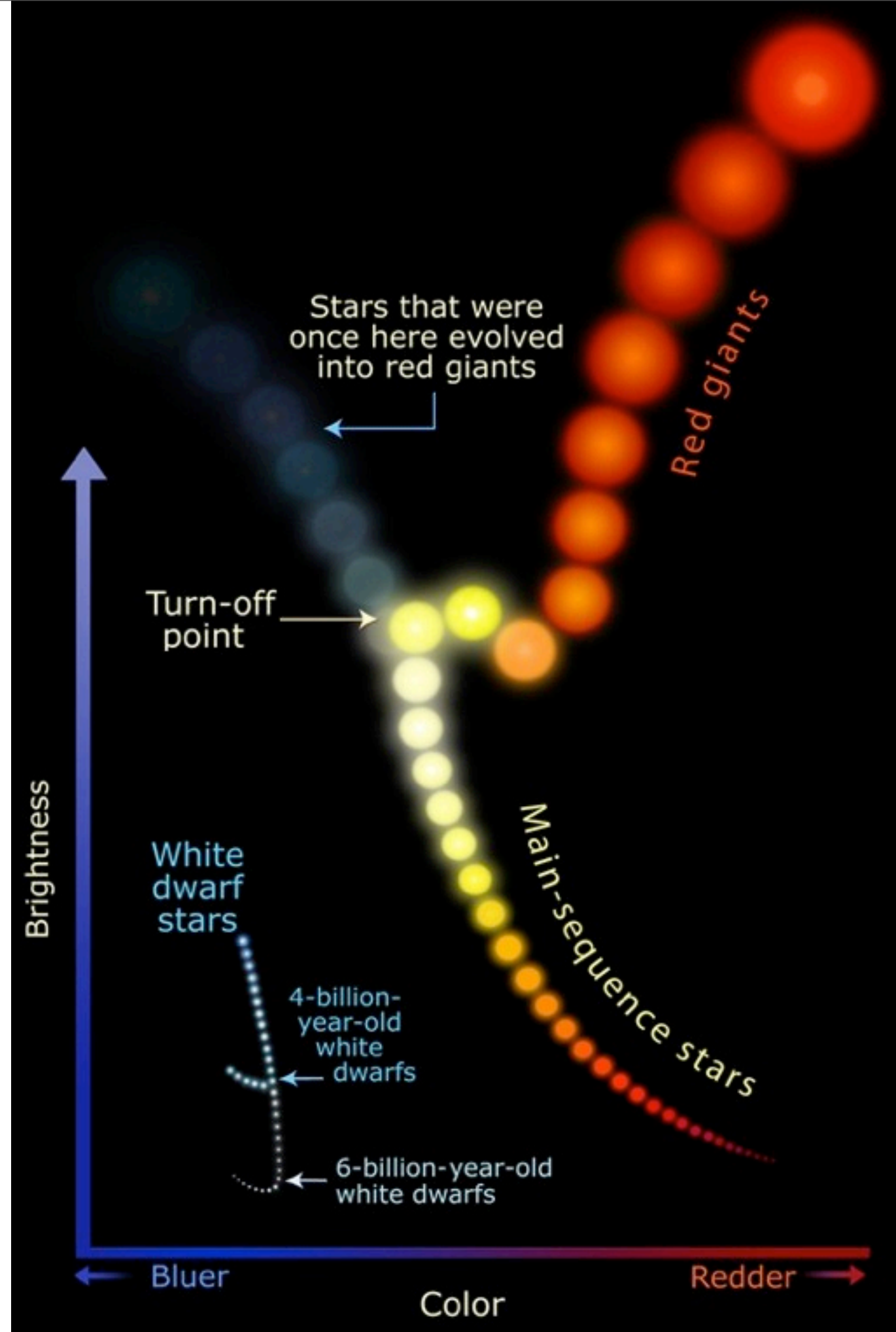
# Stars on the HR Diagram





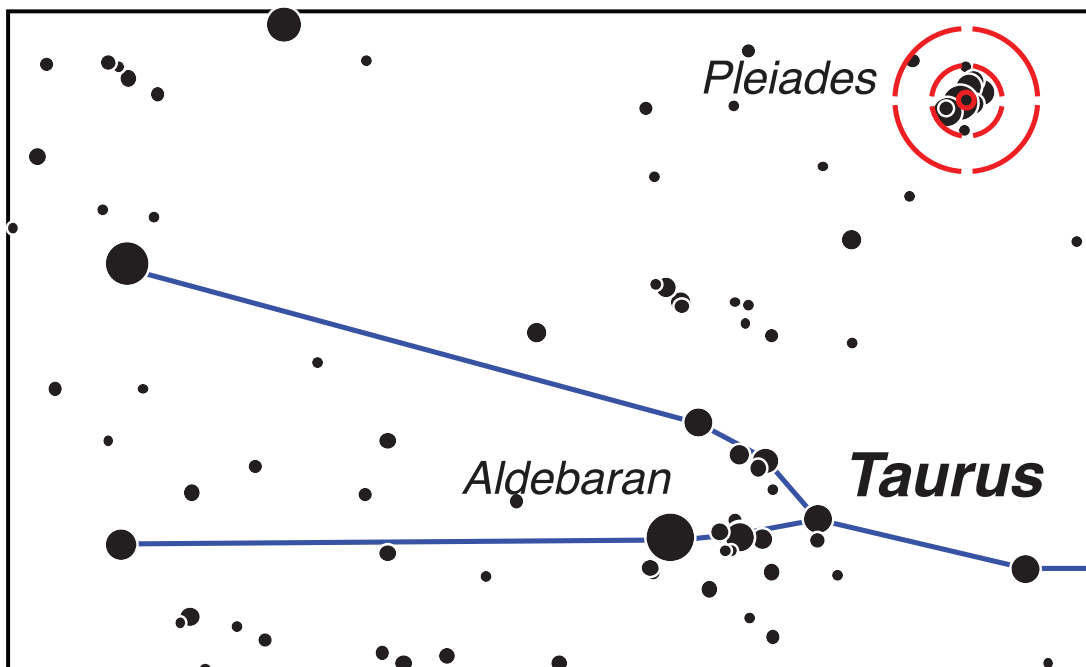
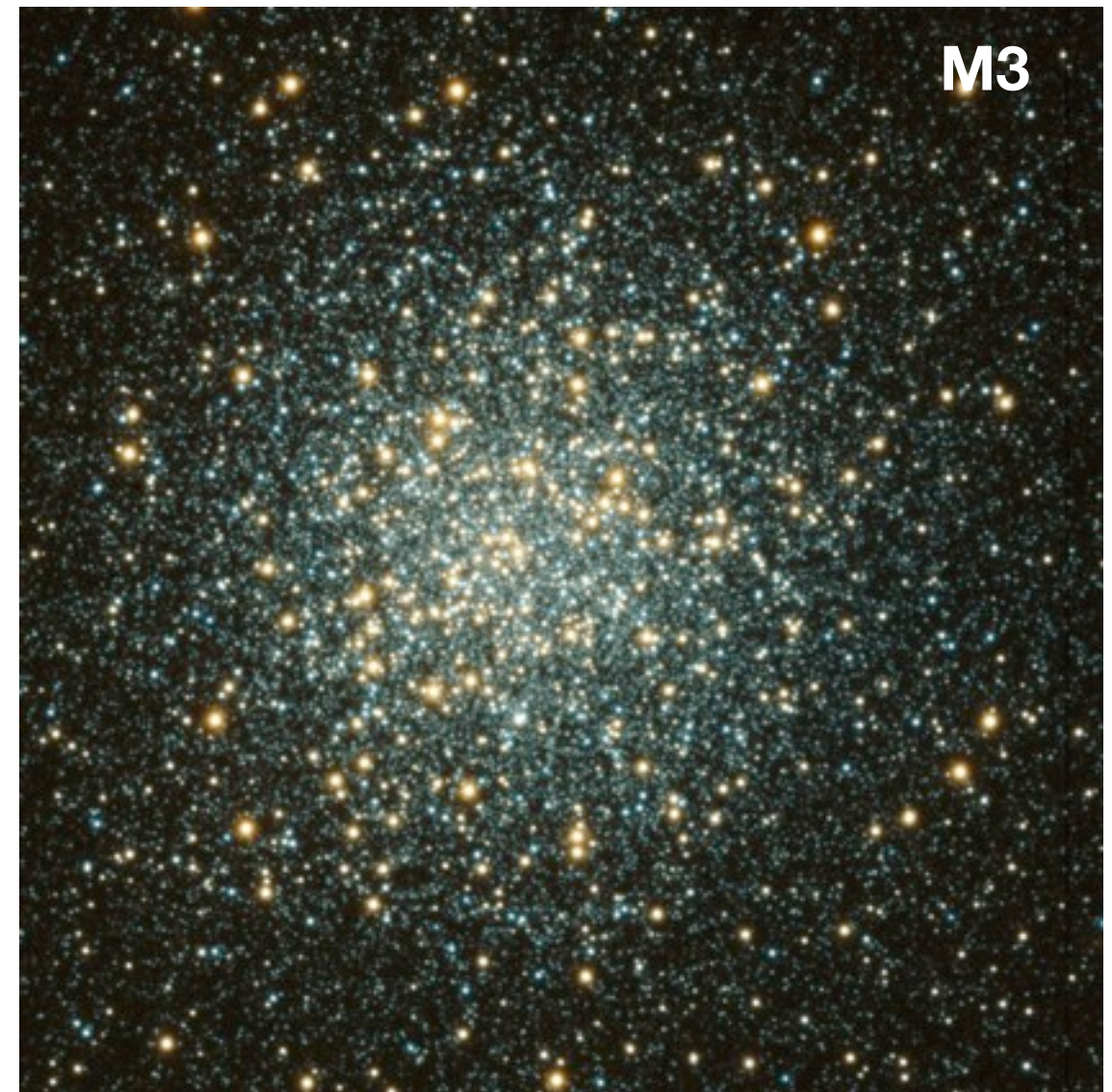
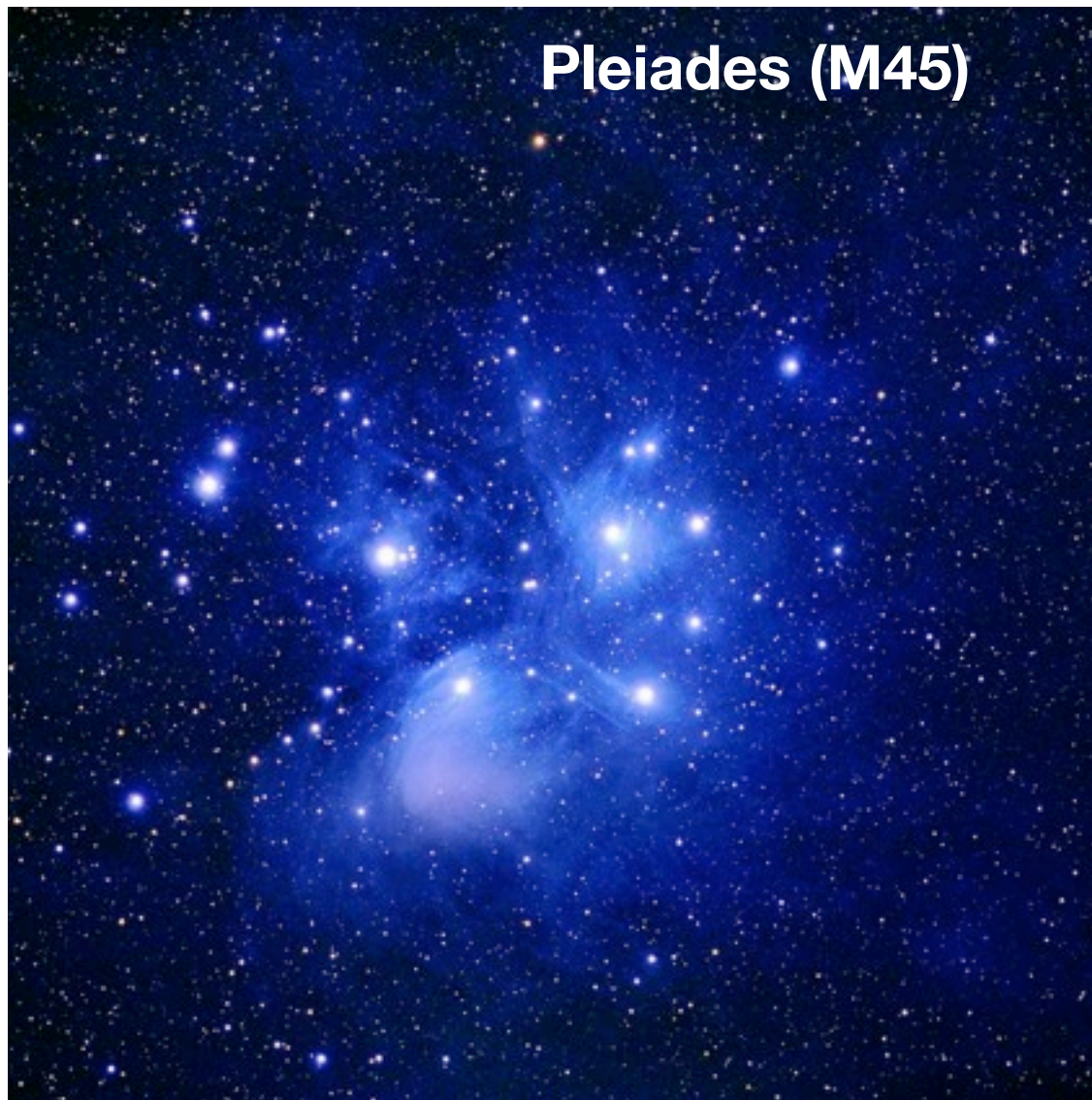
# HR Diagram & Stellar Evolution

- The HR diagram was really a tool to illuminate the entire process of stellar evolution
- Stars spend their working years (burning hydrogen) on the main sequence
- When they get old, they leave the main sequence and become red giants, then white dwarfs
- When thousands of stars are born together, some are big and some are small; *the entire main sequence is initially populated*
- Where the main sequence **turns off** is a measure of the **cluster age!**

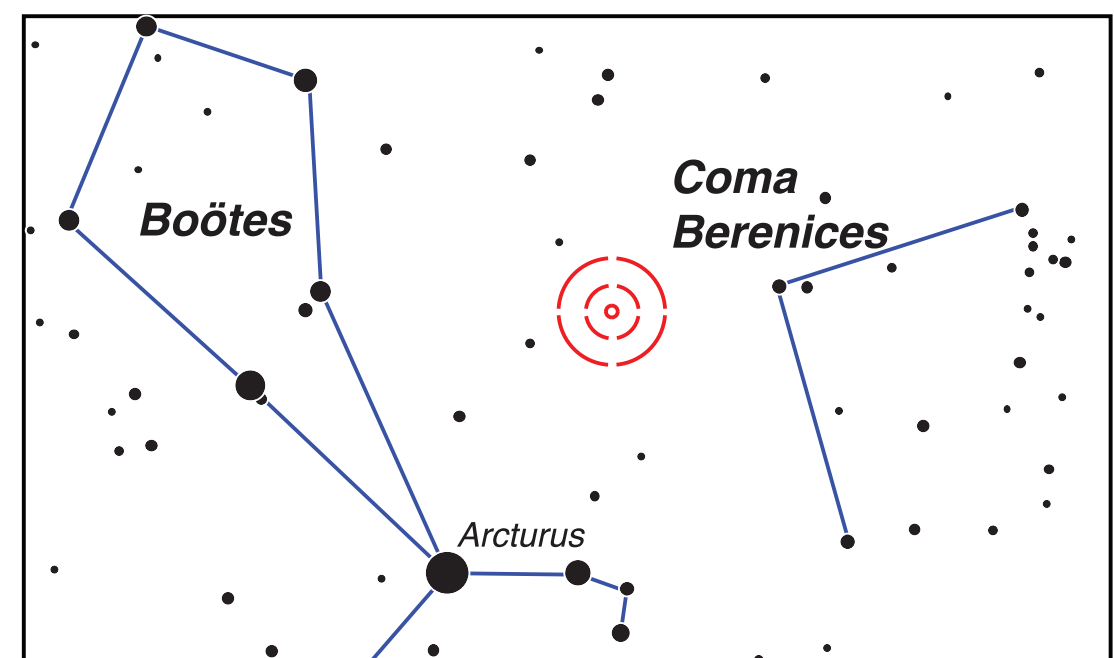




# Star Clusters

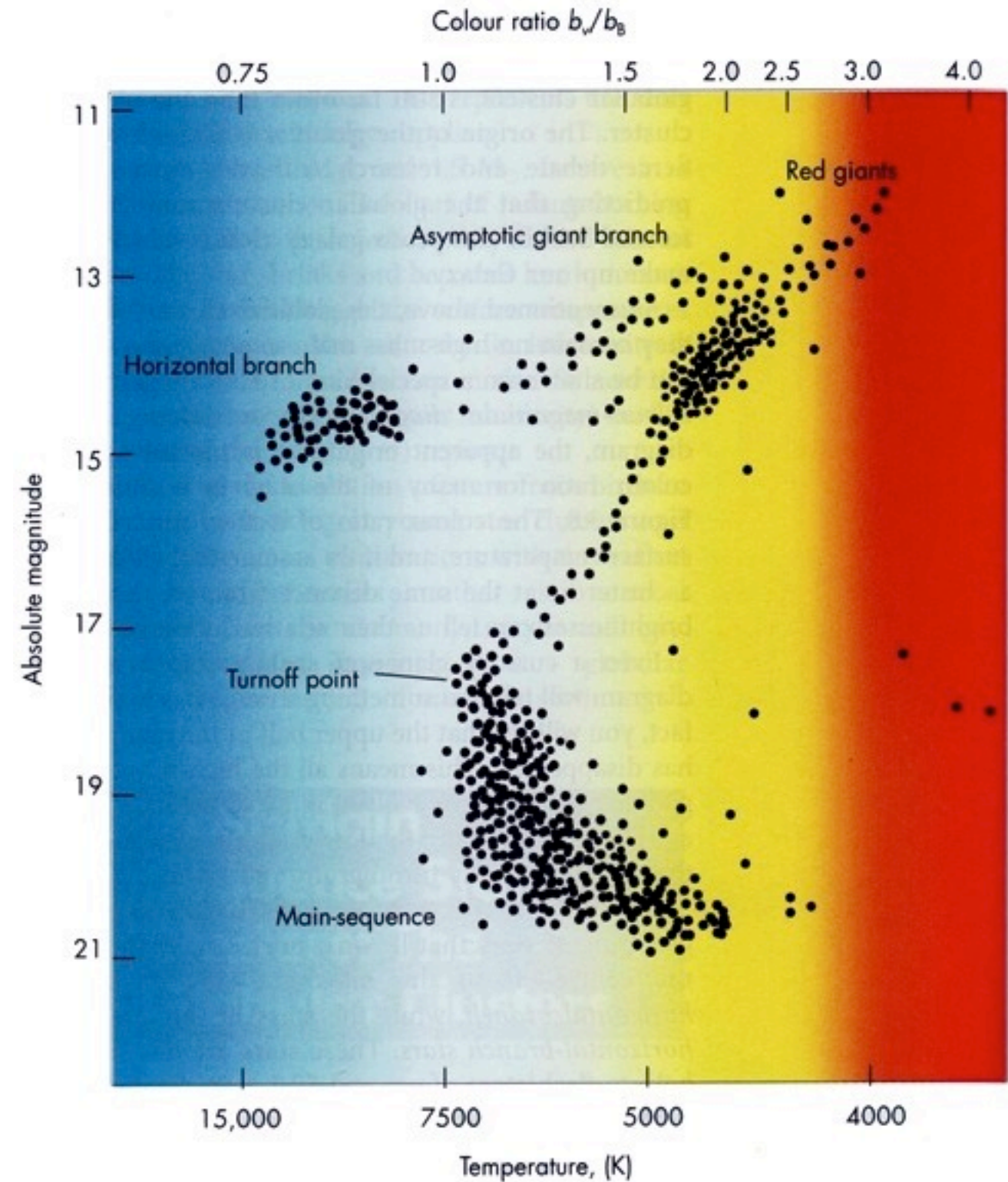
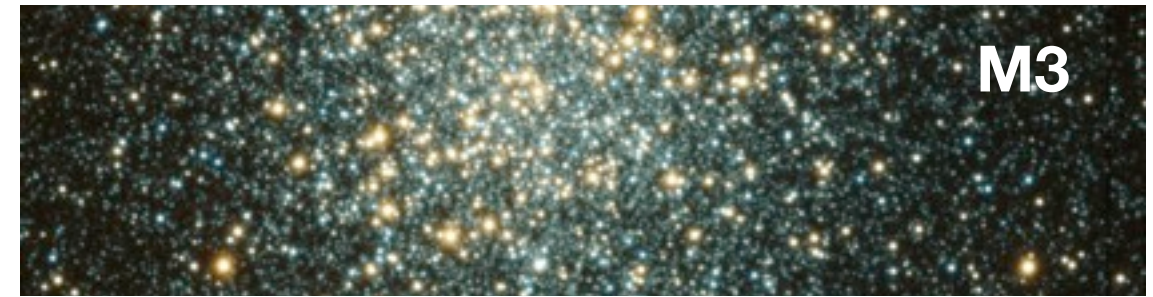
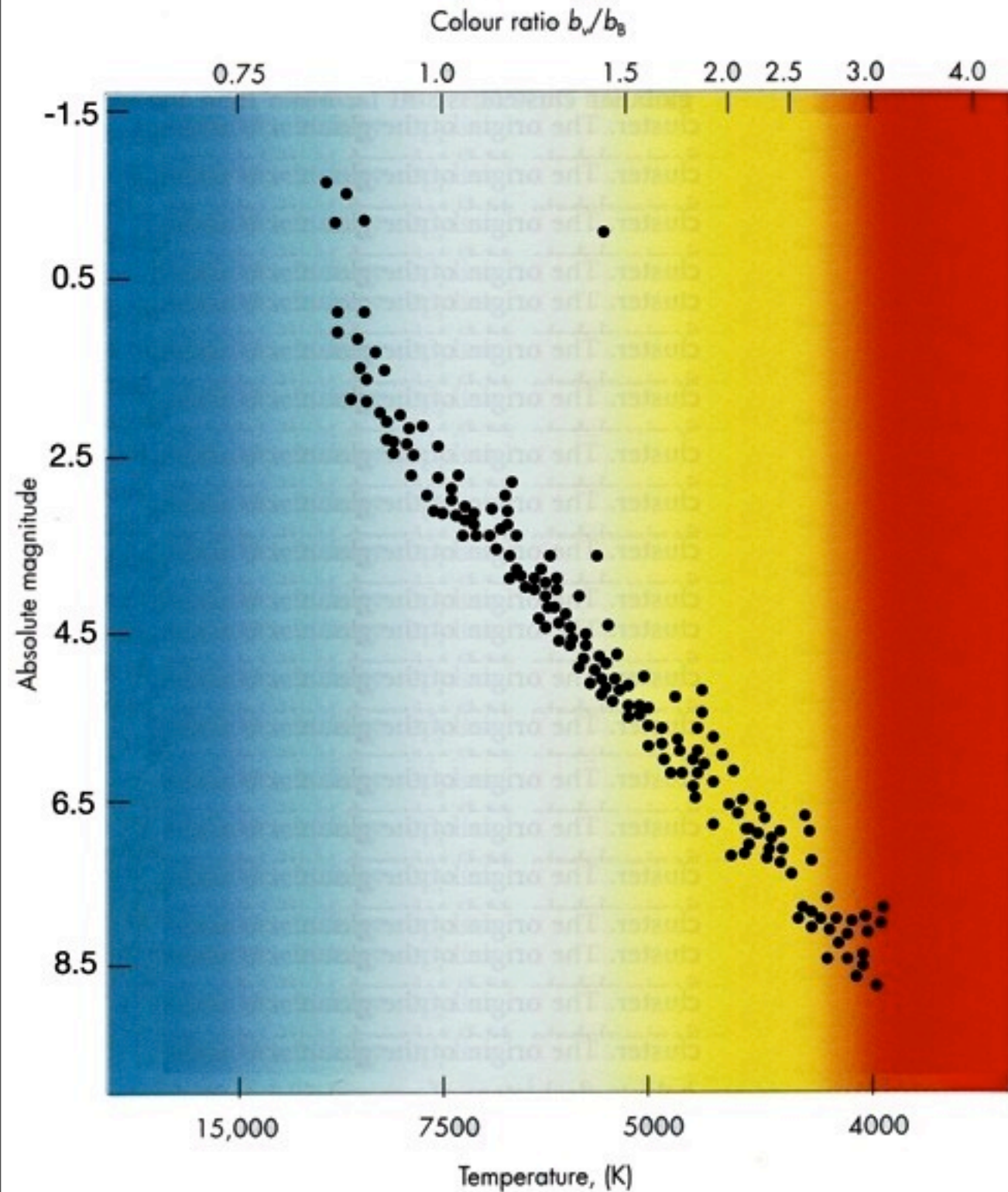


**OIY**





# Star Clusters





# *The Age of Globulars*

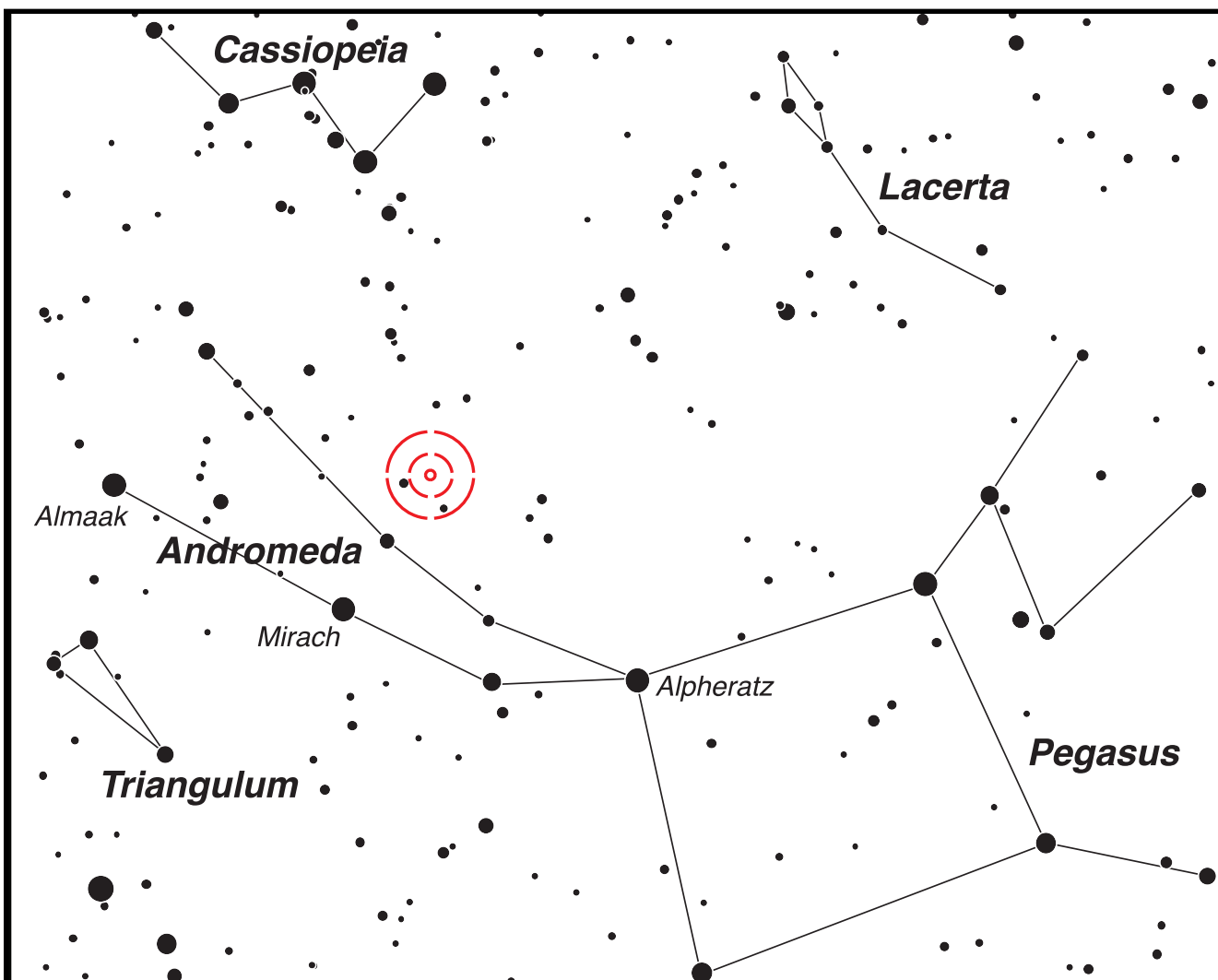
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- Globular clusters are rich in Population II stars, exhibiting very low metallicity and very little star formation
- Age estimates suggest they are between 12.5 and 13 billion years old, making them ***the oldest objects in the galaxy!***
- The globs were a point of conflict in Cosmology before we knew an accurate value for the Hubble Constant.
  - For values of  $H_0$  greater than 77 km/s/Mpc, the globs are older than the Hubble Time!



# OIY: M31

- Many M31 globulars may be resolved in the telescope!
- Rob Gendler's Mosaic
- Paul Hodges "Atlas of the Andromeda Galaxy"









# Globular Cluster Mysteries...

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- We see globulars all the time, but there is still a **tremendous amount we don't know**
- What is the dark matter content in globulars?
- How did the globulars originally form?
- What is the evolutionary history of binary stars in globulars (47 Tuc)?
- What happens when galaxies collide?
- **Where are the black holes?**
  - Globular clusters are **all bulge**



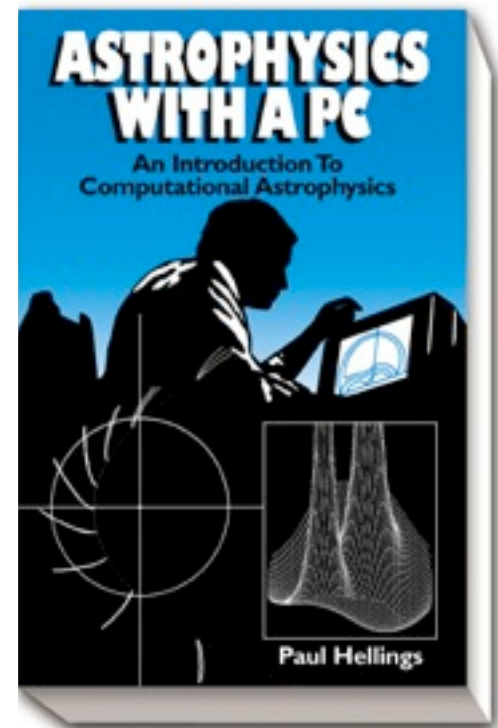
47 Tucanae



# *Globular clusters on your own...*

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- Harris Catalog of Milky Way Globbs:
  - [physwww.mcmaster.ca/~harris/Databases.html](http://physwww.mcmaster.ca/~harris/Databases.html)
- Rob Gendler Andromeda Globular Guide:
  - [www.robgendlerastropics.com/M31NMosaicglobs.html](http://www.robgendlerastropics.com/M31NMosaicglobs.html)
- ASTROPHYSICS WITH A PC (Paul Hellings)
- Sky & Telescope's Astronomical Computing columns
  - Modeling Star Clusters: April 1986 (model.bas)
  - Distributions of Globulars: December 1984 (glob1.bas, glob2.bas)
- Come to USU to study — ***I'll put you to work!***





***Thanks for coming!***

***Questions?***

